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RESEARCH ARTICLE

Development of a skim milk powder-based chocolate spread incorporated with foxtail millet and sucralose

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Abstract: The present study was undertaken to develop a dairy-based functional chocolate spread using skim milk powder (SMP), foxtail millet flour and sucralose, with the objective of enhancing nutritional value and reducing caloric contribution from sucrose. Skim milk powder was incorporated as a dairy ingredient to provide dairy solids, creamy mouthfeel and desirable spread characteristics, while foxtail millet flour was used as a source of protein, dietary fibre and minerals. Sucralose was employed as a low-calorie sweetener for partial/complete replacement of added sucrose in the optimized formulation. Different levels of foxtail millet flour (8, 10 and 12%) were evaluated for optimization based on physicochemical and sensory characteristics. Subsequently, different levels of sucralose (0.1, 0.2, 0.25 and 0.30%) were evaluated in the optimized foxtail millet-containing spread. Sensory evaluation was conducted using a 9-point hedonic scale, while moisture, titratable acidity and pH were determined using standard analytical procedures. Among the foxtail millet treatments, 10% incorporation showed the highest overall acceptability without significant deterioration in the sensory attributes compared with the control. Further, 0.10% sucralose was found to be the optimum level based on sensory acceptability. Thus, skim milk powder-based chocolate spread containing 10% foxtail millet flour and 0.10% sucralose may serve as a promising dairy-based functional spread with improved nutritional characteristics and reduced dependence on sucrose.

Keywords: Dairy-based chocolate spread, Skim milk powder, Foxtail millet, Sucralose, Functional food, Sensory evaluation

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Introduction

Chocolate spread is a beloved culinary delight, enjoyed by millions around the globe. This smooth and creamy concoction, made primarily from cocoa, sugar, and vegetable oils, offers a versatile and indulgent treat that can be spread on bread, used as a dip, or incorporated into various recipes.

A key ingredient of chocolate spread cocoa powder plays a vital role in the production. Cocoa powder provides the intense chocolate flavour and aroma that consumers love. In cocoa, there are flavanols that help to reduce oxidative stress, insulin sensitivity, and the risk of inflammation. Consuming cocoa has been linked to lower blood pressure, when high consumption of cocoa considerably lowered diastolic blood pressure that linked to reduction in cardiovascular mortality (Buijsse et al. 2006). Flavanols increase glucose absorption with reducing glucose synthesis.

Cocoa butter is a vital ingredient in chocolate spread making, imparting a rich, velvety smoothness. Derived from the fatty part of the cacao bean, cocoabutter contains antioxidants called polyphenols, which help reduce inflammation and protect the skin from sun damage (Scapagnini et al. 2014)

The SMP is an important dairy ingredient that can be incorporated into value-added dairy and dairy-based food products to improve their nutritional and functional characteristics. It provides milk proteins and other dairy solids and can contribute to desirable body, texture, creaminess and flavour. In chocolate spread formulations, SMP can enhance the creamy mouthfeel and spreadability while providing a characteristic dairy flavour that complements cocoa. The incorporation of SMP therefore provides an opportunity to develop value-added dairy-based chocolate spreads with improved nutritional and sensory characteristics. In the present study, SMP was used as the principal dairy ingredient in combination with cocoa, cocoa butter, foxtail millet flour and sucralose to develop a functional chocolate spread.

As a sugar substitute sucralose is used. It is a popular artificial sweetener commonly used as a low-calorie substitute for sugar. Sucralose is calorie-free non-glycaemic heat-stable widely used

in foods and beverages, including diet sodas, sugar-free gum, and low-calorie desserts.

Functional food refers to ingredients or products that provide additional health benefits beyond basic nutrition.These foods support specific physiological functions, like immune system support ordigestive health, making them a popular choice for health-conscious consumers (Giri et al. 2015). Foxtail millet as a functional ingredients are natively known as *Kangni, Kang* and *Kokum.* Foxtail millet was chosen for the chocolate spread due to its unique characteristics.It was selected because of its mild nutty flavour, which complemented the richness of chocolate. Additionally, its fine texture blended seamlessly into the spread, creating a smooth consistency. The millet's neutral colour also helped maintain the product's appealing appearance. Overall, foxtail millet's flavour and texture profile made it an ideal ingredient for the chocolate spread.

In view of the above justification, the present study has been designed with the objectives of (I) To optimize the level of foxtail millet addition in the dairy-based chocolate spread, (II) To optimize the level of sucralose as a low-calorie sweetener in the optimized foxtail millet-containing dairy chocolate spread.

Materials and Methods

Materials

The dairy ingredient used in the present study was skim milk powder (SMP; Sagar, manufactured by Mehsana District Co-operative Milk Producers' Union Ltd., Mehsana, Gujarat). Cocoa powder (WEIKFIELD, manufactured by Weikfield Food Pvt. Ltd., Nagar Road, Pune), cocoa butter (ISVARI, packed by Chenab Impex Pvt. Ltd., Andheri, Mumbai), cane sugar, sucralose (ELITA, manufactured by Higer Health Sciences LLP, Nandore, Palghar, Mumbai, Maharashtra) and foxtail millet flour (manufactured by The Millet Company, Kothrud, Pune) were used for development of the chocolate spread.

Methods

Preparation of skim milk powder-based control chocolate spread

All the ingredients, namely sugar, cocoa powder, SMP, and cocoa butter, were accurately measured according to the required formulation. Initially, sugar was caramelized at 170°C. Cocoa butter was then added and melted at 34–38°C, followed by the addition of the required quantities of cocoa powder and SMP. The mixture was thoroughly mixed until a uniform consistency was obtained, cooled, and stored in airtight containers under refrigeration at 4°C until further analysis.

Development of skim milk powder-based functional chocolate spread

To develop the dairy-based functional chocolate spread, cocoa butter, cocoa powder, skim milk powder, roasted foxtail millet flour and sweetening ingredients were accurately weighed according to the respective formulations. Here sucrose was completely replaced by different levels of sucralose in separate experimental batches. Initially, cocoa butter was melted and mixed thoroughly. Cocoa powder and skim milk powder were then incorporated gradually with continuous mixing, followed by the addition of roasted foxtail millet flour. In the optimized formulation, sucralose was incorporated at the respective experimental levels. The mixture was homogenized thoroughly for approximately 10 min to obtain a uniform spread. The prepared chocolate spread was subsequently cooled, filled into airtight containers and stored at 4 ± 1°C until further analysis (Fig. 1).

Physico-Chemical Analysis

Acidity- Titratable acidity of the chocolate spread was determined according to AOAC (1995).

Moisture - The sample was weighed about 5g in petri-dish, distributed the sample was properly. Then petri-dish was put into hot air oven and kept for 4h at 110±1ÚC temperature. Then the petri dish was removed from hot air oven, waited for cooling in desiccators and weighed.

Moisture= [(M1-M2)x100] /(M1-M)

Where,

M1=mass in g of the dish with the material before drying

M2=mass in g of the dish with the material after drying

M=mass in g of the empty dish

pH- Ten grams of sample was mixed with 10 ml of distilled water and a slurry was prepared thereof. The pH of slurry was determined using microprocessor controlled pH Analyzer (Sartorious brand, manufactured by Hallmark Mechatronics, Kochi, Kerala) with combined glass electrode. The pH meter was first calibrated at pH 9.2 and 4.0 and standardized at pH 7.0 using buffer solution (Giri et al. 2014).

Sensory analysis

The sensory attributes of the chocolate spread, including colour and appearance, flavour, body and texture, sweetness, spreadability, and overall acceptability, were evaluated by a panel of six faculty members of Mugberia Gangadhar Mahavidyalaya. The panellists were selected based on their interest, performance, motivation, compliance, and availability, following the guidelines

of ISO 8586-1:1993. Preliminary training was provided according to ISO 8586:1993, and two training sessions were conducted before sensory profiling to familiarise the panellists with the definitions of the sensory attributes. The samples (50 g each) were randomly coded with three-digit numbers and served at 20°C in white, 50-mL HDPE containers. The samples were presented to the panellists 2 h before or after meals. Water and bland crackers were provided for palate cleansing between samples. Sensory evaluation was performed using a nine-point hedonic scale, where 1 represented "dislike extremely," 2 "dislike very much," 3 "dislike moderately," 4 "dislike slightly," 5 "neither like nor dislike," 6 "like slightly," 7 "like moderately," 8 "like very much," and 9 "like extremely."

Statistical analysis

Statistical analysis was carried out by using SPSS software (IBM SPSS statistics trial version). One-way analysis of variance (ANOVA), Duncan's multiple range test were carried out to determine the significant differences ($p<0.05$) among different levels of foxtail millet and sucralose.

Results and Discussion

Optimization of foxtail millet level in skim milk powder-based chocolate spread

Physico- chemical analysis

Moisture

In this study it was observed that moisture percentage of control sample was 23.28 and all treated sample score were 12.31, 12.31 and 15.67 for 8%, 10%, and 12%, respectively (Fig.2). There was significant decrease ($P\leq0.05$) up to 10% as the foxtail millet addition increased. However, there was no significant difference between 8% and 10% in moisture score. That moisture percentage decreased due to addition of millet.

Acidity

In this research study it was observed that acidity percentage of control chocolate spread was 1.1 and all treated sample score were 1.2, 1.2 and 1.3 for 8%, 10%, and 12%, respectively (Fig.2). There were no significant difference ($p>0.05$) between control and all treated samples.

pH

In this research study it was observed that pH of control chocolate spread was 6.8, and treated sample scores were 6.9, 6.7 and 6.8 for 8%, 10%, and 12%, respectively. There was no significant ($p>0.05$) difference among control and three treated samples (Fig. 2).



Fig.1 Functional chocolate spread

Sensory analysis

Colour and Appearance

Colour and appearance is a crucial aspect of every food product that influence consumer approval. The colour and appearance scores of the control and treated samples (8%, 10%,12%) in the current investigation were 8.5, 8.35, 8.5,and 6.9, respectively (Fig.3). Up to 10% foxtail millet addition there was no significant ($p>0.05$) difference with control on the basis of colour & appearance. However, beyond that level a significant decrease ($p\leq0.05$) of colour & appearance was observed. The colour of chocolate spread turned darker or greyer when a higher percentage of millet was added because millet contains a higher amount of anthocyanins and other polyphenolic compounds (Dykes et al. 2006), which are naturally occurring pigments that can affect the colour of the spread. Additionally, millet has a coarser particle size than cocoa, which can also contribute to a darker or more speckled appearance. As a result, the addition of more millet altered the visual appearance of the chocolate spread, making it less appealing to consumers who were accustomed to a richer, browner colour.

Flavour

Any food product's flavour plays a key function for acceptance. Flavour is combination of smell, taste and tongue sensation on. In this research study flavour score of control chocolate spread was given as 8.8 and treated samples (8%, 10%, 12%) score were 8.8, 8.8, and 8.0 respectively (Fig.3). There was no significant difference up to 10%, and after that (12%) there was significance decrease ($P\leq0.05$). The flavour of the chocolate spread decreased when more millet was added because millet has a naturally bland and slightly sweet flavour, which diluted the intense flavour of the cocoa that contains compounds which can bind to flavour molecules, reducing their potency and aroma.

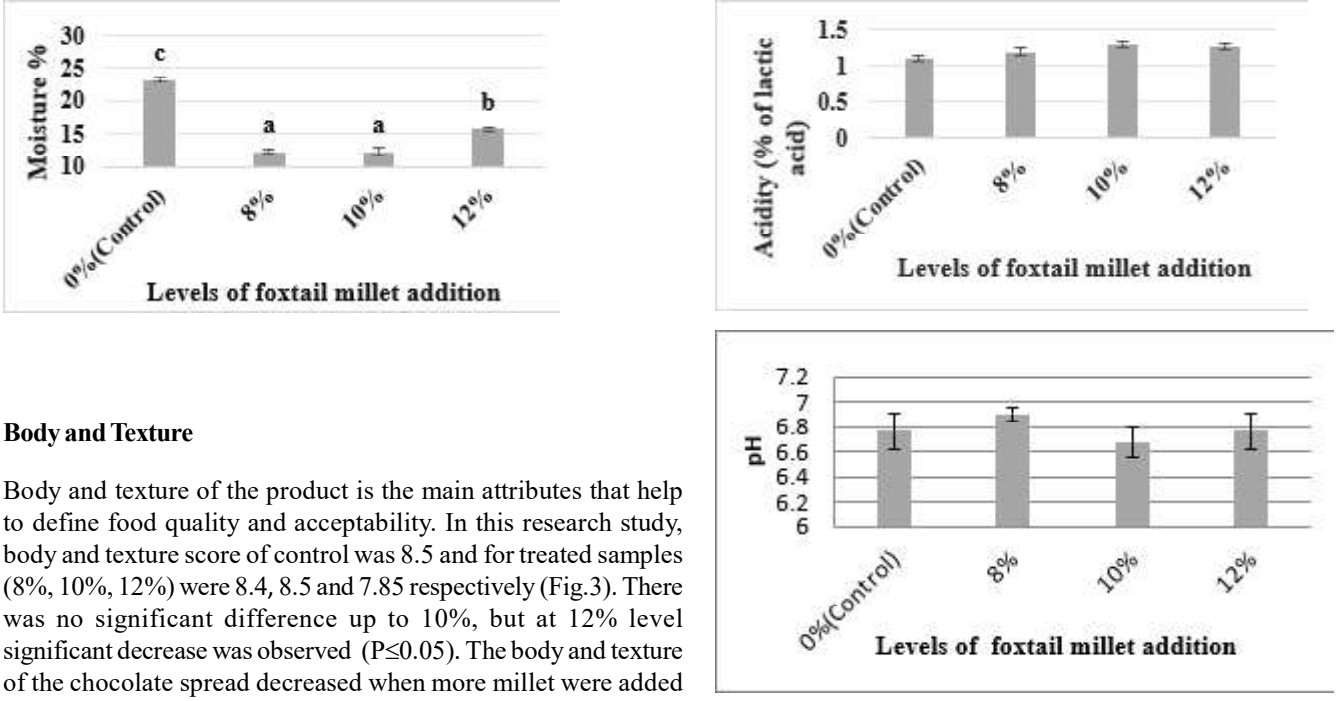


Fig. 2 Effect of different levels of foxtail millet addition on physico-chemical properties of chocolate spread; n=6; Different small alphabets indicate significantly different (p≤0.05), Vertical bars indicate standard error

Body and Texture

Body and texture of the product is the main attributes that help to define food quality and acceptability. In this research study, body and texture score of control was 8.5 and for treated samples (8%, 10%, 12%) were 8.4, 8.5 and 7.85 respectively (Fig.3). There was no significant difference up to 10%, but at 12% level significant decrease was observed (P≤0.05). The body and texture of the chocolate spread decreased when more millet were added because millet contains a higher amount of fiber and protein, which can absorb more fat and oil, leading to a drier and thicker consistency, interfere with the emulsification of the cocoa butter and sugar, causing a grittier texture resulting in a less rich and creamy spread.

Spreadability

Spreadability of the product is the main attributes that help to define spreadability of spread and acceptability. In this research study, spreadibility score of control was 8.8 and for treated samples were 8.75, 8.73, and 7.9 for (8, 10, 12%) of foxtail millet respectively (Fig.3). Among three treated samples (8%, 10%, 12%) there were significant (p≤0.05) difference between control and 12% foxtail millet. However there was no significant difference up to 10% foxtail millet addition with control. The spreadability of the chocolate spread was reduced when more millet was added because millet increased the viscosity and thickness of the spread, making it more difficult to spread evenly. Even more millet addition introduced a coarser particle size, which disrupted the smooth and creamy texture, absorbed more of the fat and oil, leaving less available to lubricate the spread and facilitate easy spreading.

Overall acceptability

In overall acceptability among treated samples (8%, 10%, 12%) there was significant difference (P≤0.05) between control and 12%, & no significant difference up to 10% was noticed. Score of the control sample and treated sample on overall acceptability of control product was 8.9 and for treated samples (8%, 10%, and 12%) scores were 8.6, 8.8 & 7.3 respectively (Fig.3). Up to 10% foxtail millet addition the sensory panelist found as per with the control on the basis of overall acceptability. So 10% foxtail millet added chocolate spread was optimized in this study.

Optimization of level of sucralose in foxtail millet added chocolate spread

Physico-chemical analysis

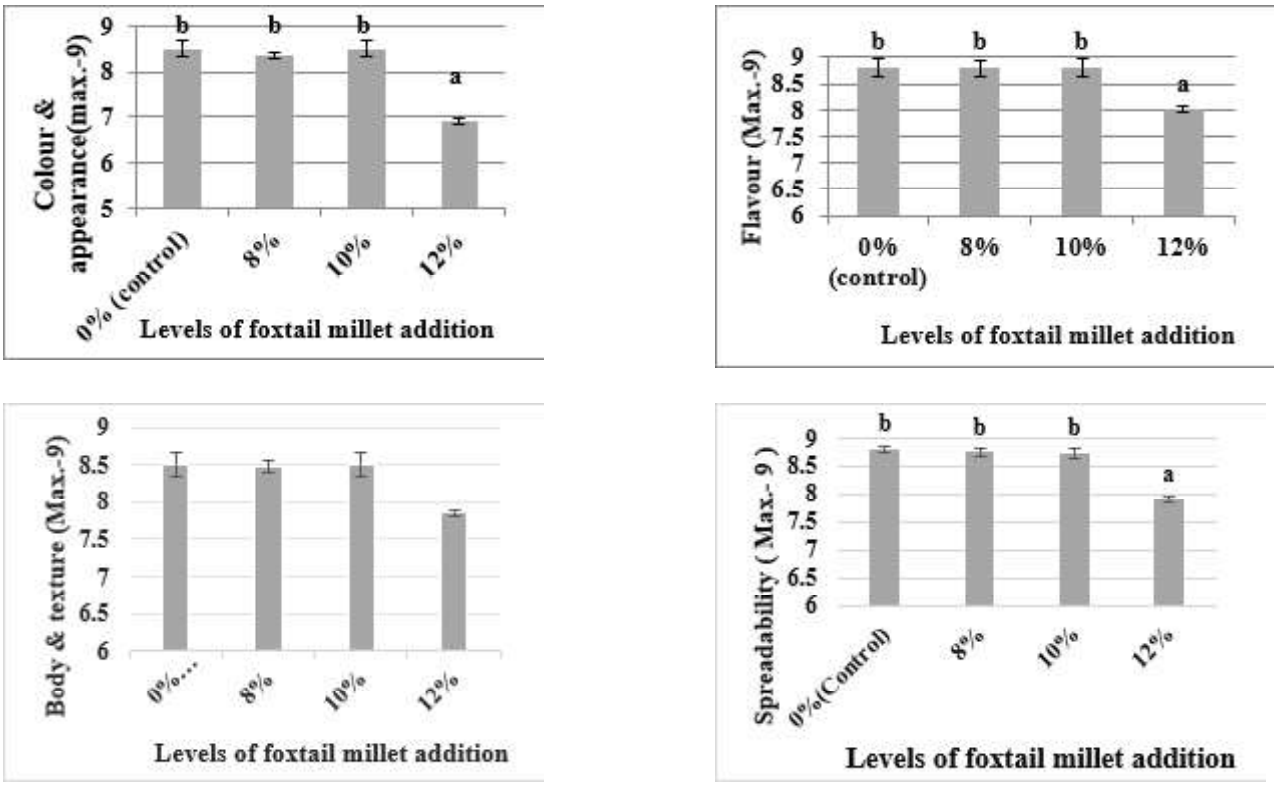
In this study control sample was 10% foxtail millet added chocolate spread which was optimized in the previous study.

Moisture

Moisture percentage of control sample was 12.31 and all treated samples of moisture were 50.40, 52.40, 59.40, 63.40 for 0.1%, 0.2%, 0.25% and 0.30% sucralose added chocolate respectively (Fig.4). There was significant increase as sucralose level increased. Sucralose had hygroscopic property. So it retained moisture, in the products.

Acidity

The titratable acidity of the control chocolate spread was 1.3%, whereas the corresponding values for the samples containing 0.1, 0.2, 0.25 and 0.30% sucralose were 2.3, 2.6, 3.0 and 3.0%, respectively (Fig. 4). A significant difference (P≤0.05) was observed among the control and sucralose-treated samples. The observed increase in titratable acidity with increasing sucralose



level may be associated with changes in the overall formulation and matrix characteristics of the spread; however, the increase should not be attributed directly to an intrinsic acidic nature of sucralose. Sucralose itself has been reported to have negligible direct effects on pH in aqueous systems. Therefore, the observed variation in titratable acidity in the present study may be considered a formulation-dependent effect and requires further investigation to identify the specific contributing components.

pH

The pH of the control chocolate spread was 6.7, whereas the pH values of the samples containing 0.1, 0.2, 0.25 and 0.30% sucralose were 5.7, 6.2, 6.1 and 6.1, respectively (Fig. 4). A significant difference (P≤0.05) was observed between the control and the sucralose-containing formulations. However, the variation in pH did not show a consistent concentration-dependent trend with increasing sucralose level. Therefore, the decrease in pH observed in the treated samples should not be attributed directly to an intrinsic acidic property of sucralose. Rather, the observed variation may have resulted from interactions among the different components of the chocolate spread matrix and differences associated with formulation and processing. Further investigation would be required to establish the specific cause of the observed pH variation.

Fig. 3 Effect of different levels of foxtail millet addition on sensory properties of chocolate spread; n=6; Different small alphabets indicate significantly different (p≤0.05); Vertical bars indicate standard error

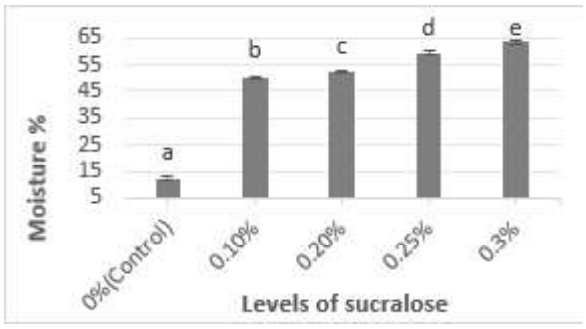
Sensory analysis

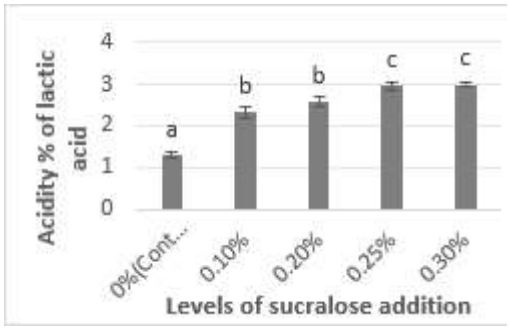
Colour and Appearance

The colour and appearance score of control sample was 8.5 and all treated samples (0.1%, 0.2%, 0.25%, and 0.3%) were 8.0, 8.3, 8.6 and 8.3 respectively (Fig.5). There were no significant difference (p>0.05) among control and all treated samples.

Flavour

In this research study score of the control sample was 8.8 and all treated samples (0.1%, 0.2%, 0.25%, and 0.3%) were 8, 8.1, 8.9 for





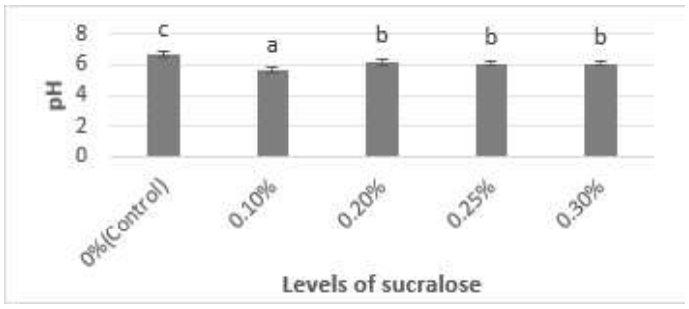
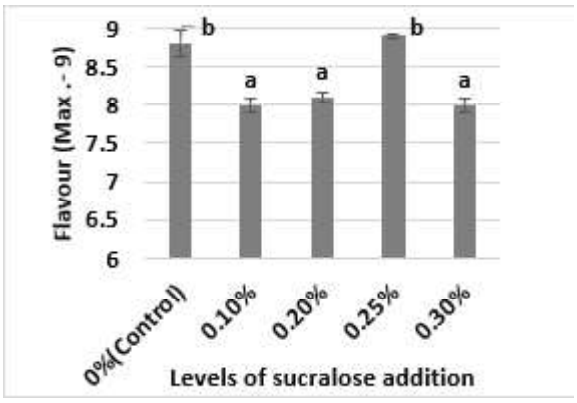
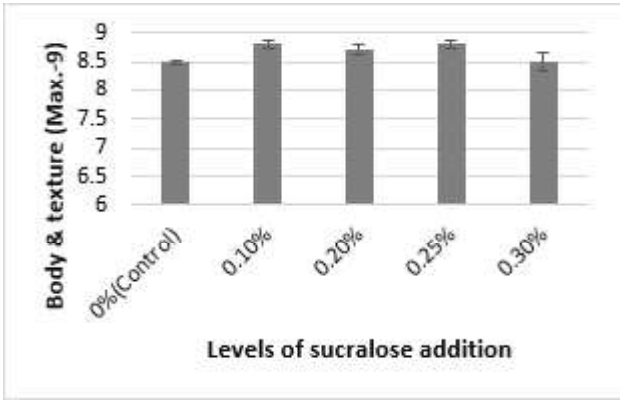
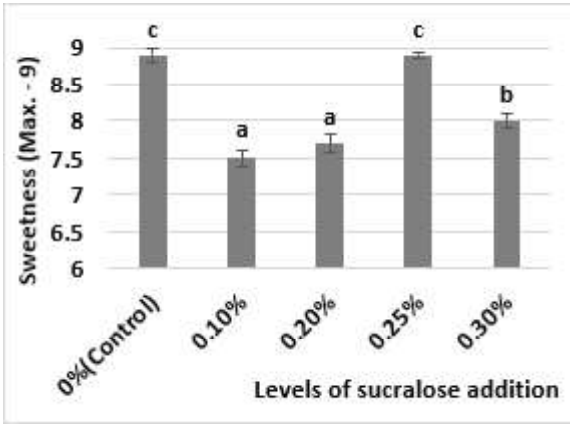
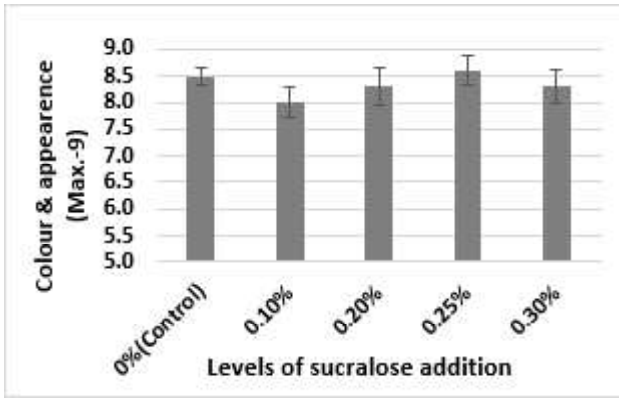


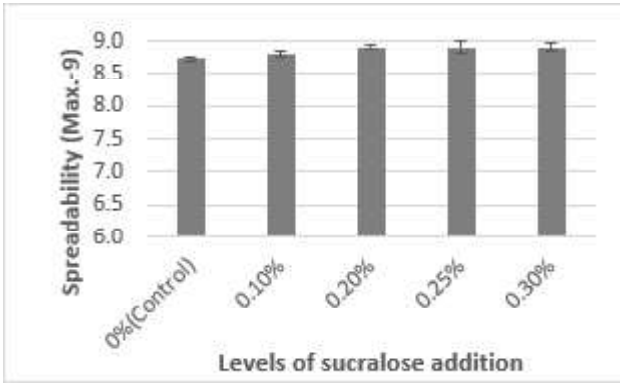
Fig. 4 Effect of different levels of sucralose addition on physico-chemical properties of chocolate spread; n=6; Different small alphabets indicate significantly different ($p \leq 0.05$), Vertical bars indicate standard error











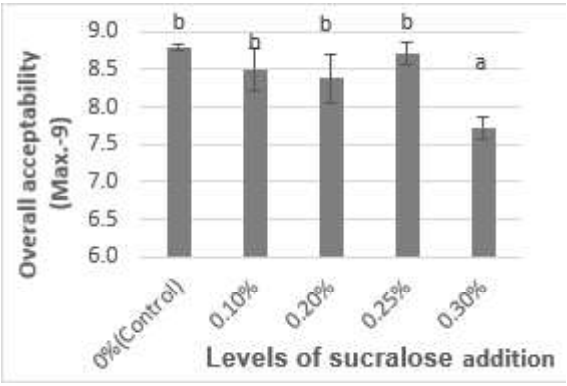


Fig. 5 Effect of different levels of sucralose addition on sensory properties of chocolate spread; n=6; Different small alphabets indicate significantly different (p≤0.05), Vertical bars indicate standard error

and 8.0 (Fig.5) respectively. There was no significant difference (p>0.05) with control and 0.25%, because a small amount of sucralose can balanced the nutty flavour of the spread. But significant difference (P≤0.05) between control and 0.1%, 0.2%, 0.3%, was noticed because a higher concentration of sucralose can overpower the other flavours, making the chocolate spread taste too sweet, which is not desirable for the spread.

Body and Texture

Body and texture score of control was 8.5 and for treated samples (0.1%, 0.2%, 0.25%, 0.3%) were 8.8, 8.7, 8.8, 8.7 respectively (Fig.5). There were no significant differences (p>0.05) among control and all treated samples.

Sweetness

In this research study score of the sweetness was 8.9 for control, and for treated samples (0.1%, 0.2%, 0.25%, 0.3%) were 7.5, 7.7, 8.9, and 8.0, respectively (Fig.5). There were significant difference (P≤0.05) among control with 0.1%, 0.2%, 0.3%, and there was no significant difference between control and 0.25%, because the sweetness intensity of sucralose is more potent than sucrose (Binns et al. 2003), the 0.25% sucralose balance with the other flavours (foxtail millet, cocoa) more effectively, creating a harmonious taste experience that masks the differences.

Spreadibility

In this research study, spreadibility score of control was 8.7 and fortreated samples (0.1%, 0.2%, 0.25%, 0.3%) were 8.8, 8.9, 8.9, 8.9, respectively (Fig.5). There were no significant differences (p>0.05) among control and all treated samples.

Overall acceptability

The overall acceptability score of the control sample and treated samples (0.1%, 0.2%, 0.25% and 0.3%) were 8.8, 8.5, 8.38, 8.71 and 7.73, respectively (Fig.5). There was significant (P≤0.05) decrease at 0.3% sucralose addition in overall acceptability score, but no significant difference were noticed among 0.1%, 0.2% and 0.25% sucralose added chocolate spread as compared to control. So 0.10% is sucralose added (minimum sucralose addition) chocolate spread was optimized in this study.

Conclusion

The present study demonstrated the feasibility of developing a skim milk powder-based dairy chocolate spread enriched with foxtail millet flour and sweetened with sucralose. Skim milk powder provided the dairy base and contributed to the desirable creamy body, texture and flavour characteristics of the spread. Based on sensory evaluation, 10% foxtail millet flour was identified as the optimum incorporation level. Further optimization of the sweetener level indicated that 0.10% sucralose provided satisfactory sensory acceptability in the optimized foxtail millet-containing dairy chocolate spread. The developed product therefore represents a potential value-added dairy-based spread combining milk solids with the nutritional benefits of foxtail millet and the reduced-sugar advantage of sucralose.

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